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Test and Study on Electrical Property of Conductive Concrete

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Abstract

The study on the electric property of the conductive concrete is of great importance to its application in the engineering construction and other new fields as there is no strict standard or specification formulated for testing the electric conductivity of the conductive concrete. This article, through the preparation of the test specimen and the contrast test of the electric property test methods of the conductive concrete, studies the preparation process of the test specimen of the conductive concrete and the test methods of the electric property of the conductive concrete. Through the analysis and research on the electrical property of conductive concrete, the author has obtained the method of mounting electrodes and the size of specimen and the test voltage of the conductive concrete.

Keywords: conductive concrete, electric property, study on test method;

1. Introduction

The conductive concrete is synthesized by mixing a certain amount of electrically conducting components (such as: graphite, steel slag, stainless steel fiber and carbon fiber) in concrete. The electric property of conductive concrete is related to the property and proportion of the conductive materials mixed into the concrete and the mixing parameters and process of concrete. The conductive concrete belongs to a functional concrete and also has the property of the structural concrete. The conductive concrete will be widely applied in the fields of building, road engineering, electric power, water conservancy, electromagnetic shielding and so on because of its electric conductivity, electrocaloric effect and electromagnetic effect[1]. Conductive concrete can be widely used in radio interference shielding,

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electromagnetic defense, building lightning protection equipment, devices to eliminate static electricity, environmental heating, building surface heating, the metal anti-corrosion cathodic protection technology, automatic control of highway, weighing the weight of moving objects, melting snow of road and airport, etc[2].

The electrical conductivity is an uppermost index of the conductive concrete, decisive to the performance and application value of the conductive concrete. It is the electrical resistivity (or electrical conductivity) that reflects the electric property. Therefore, truly and accurately obtaining the electrical resistivity data is of great importance to the research on the property of conductive concrete, to the continuous perfection of the mixing proportion and process of conductive concrete and thus to the wider application of this new functional concrete material.

2. Study on the specimen preparation process and the test method of electric property of conductive concrete

From the electrical resistivity formula:

$$\rho = R\frac{S}{L}(\Omega \cdot m) \tag{1}$$

The resistance of conductive concrete R (Ω), the area of energized material S (m^2) and the length of energized material L(m)must be measured for testing the electric property of conductive concrete.

In order to obtain the accurate test data, integrated consideration must be taken into such factors as proper resistance measuring method, suitable electrode materials, effective electrode embedding and appropriate specimen dimensions.

2.1 Design of specimen dimensions

According to its characters, the conductive concrete contains not only the conventional components of cement, crushed stones, sand and other additives, but also conducting materials. The concrete in different strength grade and the conducting materials in different proportion have different material shape. If small-size test specimen is used, the material nonuniformity will create a comparatively large measuring error, thus increasing the discreteness and error of the test data. At present, the research institutes use the test materials of different size for the test since no test standard is set up. The author selects the 150×150×450(mm) test specimens, larger than those used by any research institute, for decreasing the discreteness of the test data and ensuring the veracity of test data. The use of large size test specimens has improved the uniformity of the same group of test data and ensured the veracity of test data though such use increases the material usage, test cost and work strength [3].

The author used two groups of test specimens of different proportion for the test and made the contrast analysis of the resistivity before and after the curing of the conductive concrete. Table 1 gives the test data of two groups of test specimens prepared according to the above design scheme.

Table 1 Contrast Analysis of Resistivity of Test Specimens in Different Proportion

Specimen No.	1-1	1-2	1-3	2-1	2-2	2-3
Resistivity(0d)	9.35	9.57	9.20	7.21	7.09	7.20
Resistivity(36d)	57.61	59.26	57.25	39.68	39.78	40.37

It is known from the test result that the different specimens in the same group have very similar test result both in the early period and in the end period of curing, that is, the test data of the specimens in the

same group are basically consistent. This result has verified the author's design scheme.

2.2 Selection of test electrode materials

The electrode materials selected by the research institutes before are copper, stainless steel and mercury. Each material has its advantages and disadvantages. Considering the factors in all respects in combination with the actual situation in engineering application, the author selected galvanized iron sheet as the electrode materials, because:

(1) As far as the electrical conductivity is concerned, the tested material (conductive concrete) itself has an electrical resistivity much larger than that of any other metal materials. Therefore, selection of any metal material as electrode can meet the requirement for the test accuracy.

(2) Due to embedding being introduced, the full contact can be ensured. In the course of test, no situation took place that its poor contact caused by the loose electrode affected the test result.

(3) As far as the resistance to corrosion is concerned, although concrete, as a basic material, can corrode metal materials, so affecting the test result, its corrosion is limited within the period of test (generally 28 days or appropriately extended). In addition, the corrosion usually occurs on the part which extended out of the concrete. So long as attention is paid to the cleaning out of the dirt in the joint, the test result will not be affected.

(4) In the actual engineering application, galvanized iron sheet, galvanized angle steel and galvanized steel tube are usually selected as the electrode materials to be embedded in the conductive concrete. It is comparatively reasonable to select the similar materials as those used in the engineering practice for the test. These materials are not only used as the test electrode in the study on the conductive concrete, but also used to further study the resistance to corrosion of the galvanized materials in the conductive concrete and the influence of the corrosion extent on the electrical conductivity [4].

2.3 Study on the test method for the electrical conductivity

For the resistance measurement, account must be taken into the selection of power supply first. The conductive concrete is principally applied in the field where the power frequency alternating current is used. So the power frequency alternating current is mainly used as the measuring current in the test. However, in order to make a contrast analysis, the direct current power supply is also used in the research test.

An alternating current voltage regulator can be used to supply a wide voltage range. But because the AC voltage regulator must be equipped with an isolation transformer for guarantee the operators' personal safety, we gave up the selection of AC voltage regulator and used AC-DC low voltage power supply which is specially used in the lab. The actual application proves the voltage range fully meets the requirement of the test. In addition, we also selected the high-accuracy desk-top digital avometer in the test for reducing the test instrumentation's influence on the test data. The high-resistance digital AC voltmeter can decrease the shunting of internal resistance for ensuring the measuring accuracy.

(1) Contrast Study on 2-pole Method and 4-pole Method

In the study on the test method, the author adopted 2-pole method and 4-pole method respectively for the contrast test. The former is to insert 2 electrodes at the two ends of a conductive concrete specimen, as shown on Fig. 1(a) (top) and the latter is to insert 4 electrodes in a conductive concrete specimen, the outside 2 poles connecting the test power supply and the inside 2 poles connecting the digital voltmeter, as shown on Fig. 1(a) (bottom). The test results show that the data measured by 4-pole method are slightly smaller than those measured by 2-pole method, but their difference is small. The test results are shown on Fig. 1(b).

For the principle of test, the 4-pole method has a higher accuracy and reflects the real resistivity of materials due to its elimination of the error which is caused by the contact resistance of electrode in the 2-pole test. Through the contrast test, the author thinks that in a normal case, considering test convenience, the 2-pole method is preferred for the test. If the higher accuracy is required, it is suggested to adopt the 4-pole method for the test.

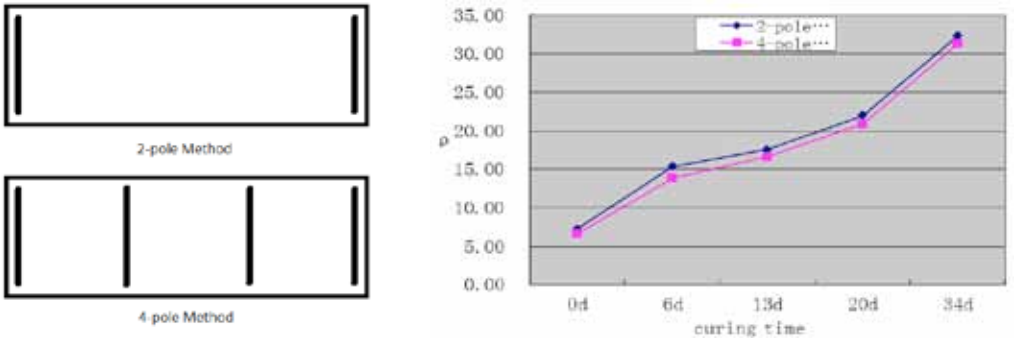

Fig. 1, (a)The Arrangement Plan of Electrodes; (b) Contrast Graph of 2-pole Method and 4-pole Method

(2) Contrast test of power-frequency alternating current and the direct current

Through the contrast test of the power-frequency alternating current and the direct current, the author has found out:

①Under the same conditions (the same specimen), the resistivity measured by the power frequency alternating current is lower than that measured by the direct current, about one third of the resistivity measured by the direct current. For the test result, see Table 2.

Table 2. Table of Contrast Test of AC and DC Power Supply

Test Power Supply	AC(4.87V)	DC(4.87V)
Resistivity(Ω. m)	0.23	0.61

②No matter whether under the AC condition or the DC condition, the resistivity of conductive concrete will decrease with increase of the voltage. But with the gradual increase of the voltage, the resistivity will go to stability. For the result, see Fig. 2.

Fig. 2 Variation of Resistivity with Different Power Supply

It is known from the above test results that the resistivity of conductive concrete is not a definite value.

It is related to the test conditions, such as the size of specimen, the test method, the selected power supply, high or low voltage, and so on. In order to really reflect the electrical property of conductive concrete, the supply voltage used for measuring the resistivity should be selected in the voltage value after the resistivity goes to stability, as the values over 10V voltage shown on Fig 2. At the same time, it should be noted that the power supply used for the resistivity measurement is the power frequency alternating current or the direct current. These data will provide the basis for reference when the conductive concrete is used on the different environmental conditions [5].

3. Conclusion

Through the analysis and research of the electrical property of the conductive concrete, the author has come to the conclusion as follows:

(1) When the specimen is 150×150×450 (mm), using the galvanized iron sheet as the electrode material for the test by 4-pole method can ensure the uniformity and accuracy of the test data to a large extent.

(2) The power frequency alternating current should be used for the test to make the test data close to the actual engineering application.

(3) No matter whether under the AC condition or DC condition, the resistivity of conductive concrete will decrease with increase of the voltage. But with the gradual increase of the voltage, the resistivity will go to a stable vale.

(4) The supply voltage selected for measuring the resistivity of conductive concrete in the test must be a value in the stable region of the resistivity.

Through the analysis and research on the electrical property of conductive concrete, the author has obtained plenty of data for the preparation and the electrical property test of conductive concrete. These data has laid a good foundation for the study on the electrical property of conductive concrete and its application study.

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